Using attitude formation towards novel stimuli to predict changes in depressive symptoms

Senior Honors Thesis

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Abstract

Prior research has shown that depressive symptoms are cross-sectionally associated with a learning asymmetry characterized by poorer learning about positive stimuli relative to negative stimuli. This study offers the first prospective test of this relation to determine if this learning asymmetry predicts change in depressive symptoms over time. A sample of 123 undergraduates completed a computer measure of learning asymmetry and questionnaire measures of depressive symptoms early in the academic quarter. Measures of depressive symptoms were again collected near the end of the quarter. Results did not replicate the cross-sectional effect seen in previous studies nor did the association emerge prospectively. However, in a subsample of participants who learned at or above chance levels on the computer task, the hypothesized pattern emerged. Among participants who learned well, a negative learning asymmetry predicted increases in depressive symptoms across the quarter. Additionally, exploratory analysis of the potential relationship between learning asymmetry and effortful control (EC), a self-regulatory capacity that allows one to override reactive/automatic processing of mood-relevant stimuli, showed that EC did not modify the relationship between learning asymmetry and depressive symptoms.

Introduction

Mood disorders are the most common of all mental disorders. They affect millions of people on a day-to-day basis. Major Depressive Disorder (MDD) is one of the most common diagnoses in the Diagnostic and Statistical Manual, 4th Edition (DSM-IV). Major Depressive Episodes (MDE) often accompany many medical conditions such as heart disease, diabetes, asthma, and obesity (Scott et al., 2007). These statistics make depression one of the largest health-care burdens in the world. Therefore, developing more complete theory regarding the etiology and maintenance of depression should be a top priority in clinical research. One of the well established features of depression is that depressed individuals show biased cognitive processing of various life events and stimuli. Two of the most well supported cognitive models of depression are Beck's Cognitive Theory of Depression, and Hopelessness Theory. There are subtle differences between each model, but both can be viewed as diathesis-stress models of depression.

Beck's Cognitive Theory of Depression (1967; 1987) posits that individuals with dysfunctional attitudes about themselves are at risk for the development of depression. Beck theorizes that these dysfunctional attitudes are formed early in life in response to unpleasant events. These attitudes are incorporated into the cognitive system in a lasting way, taking the form of negative self-schemas. Later in life, whenever a negative or ambiguous event occurs, these negative self-schemas are activated. It makes good evolutionary sense that in the face of aversive or threatening objects, the cognitive system allocates extra attention to threatening objects in order to form a plan of action and escape harm. In modern society, however, the average person has fewer encounters with poisonous snakes, spiders, or other potential life-threatening situations, and more experience with social rejection or failure to complete an important life-goal. When a person experiences a negative event, (i.e. failing a math test), their negative self-schemas lead them to make absolute inferences about themselves, their world, and their future (i.e. “I am a failure” rather than “I failed at this task”). Making generalizations about the self, the world, and the future is referred to by Beck as the negative cognitive triad.

Hopelessness theory (Abramson et al., 1989) states that a global-stable attributional style interacts with negative life-events to produce hopelessness, which in turn produces symptoms of depression. Whenever a negative life event occurs, individuals prone to depression tend to make global generalizations, and believe that their opportunity for success will never improve. These judgment errors can be seen more clearly in a simple example. John is rejected when he asks to go on a date with Jane. Instead of realizing that there could be many factors involved in Jane’s decision, such as an already existing relationship, he attributes this failure to the fact that Jane does not find John desirable, but also, that no woman wants to date him (global), and that this is simply never going to change (stable).

Although there are subtle differences between Beck’s model and Abramson’s Hopelessness theory of depression, it is easy to see how similar they are. Both theories view the development of depressive symptoms within the framework of a diathesis-stress model. That is, both models present specific cognitive risk factors in the development of depression, and both models assert that the cognitive risk factors only lead to depression in the presence of negative life-events or threatening stimuli. Both theories focus their attention on the maladaptive cognitive processing of negative life-events or negative stimuli, and how this produces feelings of low self-worth and negative affect (Spangler et al., 1997). However, depression is not only characterized by symptoms of dysphoria, but also anhedonia.

Anhedonia is defined as a loss of the ability to experience pleasure from stimuli or acts which would normally produce it, and it is considered to be an essential symptom of depression (DSM-IV). Multiple studies show that depressed individuals display a dulled responsiveness to rewarding cues (Sloan, et al., 2001; Suslow, et al., 2001). For example, White, Ratcliff, Vasey and McKoon (2009) found that dysphoric individuals displayed a memory deficit for positive words relative to non-dysphoric participants. In addition, depressed individuals also show hypoactivation in brain areas known to be involved in reward (Gotlib et al., 1998; Tremblay et al., 2002). Such evidence suggests that that impaired processing of positive stimuli and rewarding experiences is just as important to depression as excessive processing of negatives. Therefore, it is important to understand how cognitive processing of both negatives and positives is related to depression. Future diathesis-stress models of depression will need to account for cognitive processing of *both* negatives and positives in order to most efficiently model depression. A recently developed computer program was designed to analyze how well participants were able to learn about positive (rewarding) objects, as well as negative (punishing) objects.

A study done by Fazio, Eiser, and Shook (2004) designed and utilized a computer program called *Beanfest* to examine the learning of objects, and how the attitudes from learned objects generalized to novel objects. The objects in this game were referred to as beans, hence the name *Beanfest*. The goal of the game was to gain as many points as possible by learning the characteristics of each bean. Some beans were rewarding, and increased participants' scores, while other beans punished participants by decreasing their scores. Each bean differed in both its shape, and its number of speckles. Beans were presented one at a time and participants were given the choice to approach that bean, or avoid it. Later in a memory task, participants were presented with beans found in the game phase as well as new beans they had not previously encountered. Participants were tested on their memory of game beans (i.e. "Was this a good bean or a bad bean?"), and also the attitudes that they generalized to new beans, based on their similarity to game beans.

Results revealed a learning asymmetry, in which positive beans were more poorly recognized than negative beans. In addition, a generalization bias was found. When presented with a new, unfamiliar bean, it required less similarity to a negative bean for the bean to be labeled a bad bean than was required if the unfamiliar bean resembled a good bean. In addition, beans which were equally similar to known negatives and known positives were more likely to be judged as negative.

In the original game, feedback about the valence of a bean was contingent upon approaching a bean, similar to the way in which feedback works in real-life scenarios. If a bean was avoided, it had no effect on a participant's points, and the participants learned nothing about it. However, when feedback was manipulated such that the point value of the bean was displayed regardless of whether it was accepted or rejected, the learning asymmetry was reduced. Thus the learning asymmetry was largely a function of sampling bias in this original study. Those who did not approach as many beans therefore learned less about the bean world and thus believed more beans to be negative than really were. This sampling bias is distinct from a learning bias, which was tested by using the full-feedback version of the game in which the valence of each bean was displayed after every trial, regardless of whether the bean was accepted or rejected. In this case, some individuals still displayed the tendency to remember negative beans better than positive beans, and therefore persisted in displaying a learning bias.

Shook, Fazio, and Vasey (2007) further examined this learning bias under full-feedback conditions and found that when Beanfest learning was correlated with measures of poor cognitive style, depression, and anxiety, there was a significant relationship. Shook et al. examined relations with the Cognitive Style Questionnaire (CSQ; Abramson et al., 1998), the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996), and the Beck Anxiety Inventory (BAI; Beck, et al., 1988). Specifically, they found that these measures were correlated most strongly with poor learning of positive beans.

Conklin, Strunk, and Fazio (2009) further examined previous findings relating the learning bias found in *Beanfest* to depression. Clinically depressed vs. non-depressed control subjects were assessed in their learning of positive beans and in their learning of negative beans. Results revealed that depressed individuals did a poorer job of learning positive beans than non-depressed individuals. Depressed subjects did not differ in their learning of negative beans, however. In addition, when looking at the depressed group, learning asymmetry was correlated with symptom severity. Thus, displaying more severe depressive symptoms coincided with a larger magnitude of the learning asymmetry. Conklin et al.'s findings presented validation for the original finding of Shook et al. that depression is related to poor learning of positive beans in the *Beanfest* task. Further, it extended the finding to clinical populations of depressed individuals.

The current research effort attempted to further examine this relationship between depression and poorer appreciation of positive stimuli. The Shook et al. (2007) findings established evidence for this relationship, and Conklin et al. (2009) findings replicated this relationship in a clinical population. The current study was intended to again replicate those findings. What is not known about the relationship between learning asymmetry and depression is how the relationship holds over time. Beyond establishing that there is, in fact, a relationship at a single time point between the learning asymmetry and depression, it is necessary to determine whether *Beanfest* can be used to predict future depressive symptoms. One possible explanation for the relationship is that depressed individuals display a learning asymmetry *because* they are depressed. In that case, a learning bias in which positives are learned more poorly than negatives would represent a symptom of depression. It is also possible that a learning asymmetry involving poorer learning of positives presents a risk factor for the development of depression, or at least increases in depressive symptoms over time. This study attempted to link *Beanfest* scores at the beginning of the academic quarter to an increase in depressive symptoms throughout the quarter, when controlling for baseline depressive symptoms. Previous studies utilizing *Beanfest* scores did not use dependent variables which differentiated between dysphoric and anhedonic symptoms of depression. The current study included an additional measure, the Depression Anxiety Stress Scale (DASS; Lovibond & Lovibond, 1995), which distinguishes dysphoric and anhedonic symptoms of depression. This allowed the current study to further examine the underlying cognitive system which is most involved in *Beanfest*.

In addition to attempting to predict future depression using *Beanfest*, the study exploratorily examined the possible moderating effects of effortful control (EC) in predicting depressive symptoms. Effortful control is a conscious process which allows one to override his or her reactive tendencies towards threat processing and reward sensitivity. As its name implies, effortful control requires effort on the part of the individual in order to reallocate attention to less threatening aspects of a stimulus and to engage in activities that may not initially feel rewarding. The ability to push through feelings of discomfort or nervousness in order to give a speech to a large group of people is an example of exercising EC. Persisting in the face of a lack of motivation to complete a final paper is another demonstration of the use of EC (Harris et al., 2006). Furthermore, effortful control has been shown to have a significant moderating effect on negative affect's and positive affect's relation to depression (Clark & Watson, 1991; Derryberry & Rothbart, 1997, 2002; Lonigan et al., 2004). Individuals who are prone to greater threat sensitivity and negative affect are normally at a greater risk for the development of depression. Similarly, those with low approach tendencies, and less sensitivity to reward are also at a greater risk for developing depressive symptoms. However, if these individuals are also high in EC, they are able to overcome their reactive tendencies, and show no greater depressive symptoms than individuals who do not display maladaptive reactive tendencies. This relationship has been shown both cross-sectionally and longitudinally, among adult populations as well as child and adolescent samples.

It was hypothesized that learning asymmetry would be related to depression observed at the beginning of the quarter (a replication of the cross-sectional relationship found in previous studies). In addition, it was expected that the learning asymmetry obtained at the beginning of the quarter would predict increases in depression across the course of the quarter, thus providing evidence that poor learning of positives is a risk factor for depression.

Method

Participants

Ohio State University undergraduates were recruited using the university REP subject pool in which introductory psychology students were awarded with credits required for their course by participating in the study. There were 143 undergraduates who began the study, but only 123 completed all relevant aspects of the study. Most participants were in their freshman or sophomore years of college (90%) and the mean age was 19.16 years old (range: 18-40). A majority of the participants were female (62%). Participants were paid for their performance on *Beanfest*. Every time they reached 100 points during the game phase, they were awarded with $1. For every game they lost, $.50 was subtracted from their winnings. The maximum amount of money that could have been won was around $10, but this would have required 100% accuracy of identifying positive beans and rejecting negative beans during the game phase (a virtual impossibility). In the actual sample, the maximum payment was around $6. Payment was intended to motivate participants to perform their best on the task.

These 123 individuals were invited to participate based on their scores on screening measures of EC as well as emotional reactivity. Emotional reactivity was assessed using a trait version of the Positive and Negative Affect Scales (T-PANAS; Watson, Clark, & Tellegen, 1988). EC levels were determined based upon subjects' answers a questionnaire which combined selected items from two measures of EC, the Attentional Control Scale (ACS; Derryberry & Reed, 2002) and the Effortful Control Scale (ECS; Lonigan & Phillips, 2001). All individuals whose emotional reactivity scores and/or EC scores fell above or below cut-off scores established in previous research as defining the boundaries of the upper and lower quartiles received an e-mailed invitation to participate in the study. Simultaneously, a random sample of all others who completed the screening measures was also invited to participate. The goal of this procedure was to oversample the extremes of these variables in order to maximize variability on the constructs of interest. However, it should be noted that the distribution of emotional reactivity and EC scores for the resulting sample closely approximated normality.

Equipment

Beanfest is a computer program used to assess the recognition of positive and negative objects in one's environment. Each of the computers equipped with Beanfest is outfitted with a monitor, a mouse, and a specially marked keyboard for responses. The game itself presents participants with stimuli which are referred to as "beans" (see Figure 1 in Appendix A). Each bean has a point value attached to it. Participants are tasked with gaining as many points as possible by learning the valence of each bean and approaching the good beans while avoiding the bad beans. Beans are varied in two ways: shape (circular to oblong) and number of speckles (1 to 10). This creates a 10 x 10 matrix of beans (see Figure 2 in Appendix A). Six particular regions of the matrix are selected to be presented during the game phase of the task. These regions of the matrix are selected to have positive or negative values. These regions are selected as such in order to offset any simple linear trend. In other words, there are equal numbers of positive circular beans and positive oblong beans. Participants cannot form a simple rule that circular beans are good and oblong beans are bad. The same principle of controlling for a simple linear relationship applies to the number of speckles as well.

When a participant plays Beanfest, the beans themselves appear in the central region of the computer screen. In the lower left region of the display, the participants' decision to accept or reject a bean is shown as "yes" or "no" and the point value of each bean is displayed. On the lower right, the score is displayed both as a number and as a bar, which is completely filled at

100 and completely empty at 0. Each bean shown during the game phase is worth +/- 10 points. Both the score and the information about the bean are updated after every trial. If a bean is accepted, the score will be adjusted accordingly, but if it is rejected the points are not altered.

In some versions of the game, feedback about the valence of the beans is contingent upon accepting a bean. This is analogous to a real life situation in which it is necessary to approach and interact with a person in order to gain any information about what that person is like. The version of the game used in this study, however, was the full-feedback version of the game. This version does not depend on acceptance of a bean for gaining insight about its characteristics. Non-contingent feedback allows for a pure test of the learning bias without the confounding effects of the sampling bias.

Procedure

Participants were brought into the lab at three time points, although only the first session at the beginning of the academic quarter and the final session at the end of the quarter were relevant to this particular study. *Beanfest* was only administered at time point one, while self-reported depressive symptoms were collected both at the beginning of the quarter and at the end. When participants entered the lab for the first session, they always completed the *Beanfest* task first, followed by filling out various questionnaires involving self-reported depression and other constructs not relevant to this study. For completion of Beanfest the experimenter read scripted instructions to participants. Participants were also provided with a written copy of instructions to follow along with (see appendix for a copy). The *Beanfest* task is divided into three consecutive sections. The details of each are as follows:

Practice Phase: To familiarize participants with the interface of *Beanfest*, the program presented a block of six trials, with each trial being defined as the presentation of a bean. Each bean was drawn from one of the six regions shown in the matrix. This allowed the participants to gain a fundamental understanding of how the point system works and begin associating beans with their values. Point values were displayed, but for demonstrational purposes only, as they were not counted towards the participant's point total yet. The experimenter stayed in the room during the practice phase in order to give participants a chance to ask any final questions about the program before the game phase began.

Game Phase: After the six trials in the practice phase were complete, the game phase began. This is the phase in which participants were attempting to score as many points as possible. Scores started at 50 and the goal was to reach 100 and avoid being brought down to 0. The game phase was divided into three blocks, each containing 36 trials. Only the 36 beans which were assigned values in the matrix were presented during this phase, meaning that each of the 36 beans were presented three times over the course of the game phase. If a participant's score reached 100, they were credited with winning a game and their points were reset to 50. If their point total fell to 0, they lost a game and their points were reset to 50 and they continued trying. Winning or losing a game did not alter the presentation of the beans, however. The presentation of beans was random except for the first 12 trials in the first block, which were fixed to prevent early losses due to a random string of negative beans, which might have biased participants towards avoidance. Regardless of the number of games won or lost, the game phase always ended after the 3 blocks of 36 trials had been completed and each bean had been shown three times.

Test Phase: After the game phase, participants were again given a set of oral and written instructions on how to complete the test phase of the game. The test phase contained no point meter or feedback, and the goal of participants was not to accumulate points, but to simply judge whether the presented bean was good or bad. All of the beans from the 10 x 10 matrix were presented to participants during this phase, meaning that there were beans that they saw in the game phase as well as novel beans. Beans were presented in two blocks of 50 trials each, and participants were given ten seconds to judge the valence of each bean. This is the phase of the game which was used to assess the correct learning of the game beans.

Measures

Beanfest Variables: There were two primary outcome variables gathered from *Beanfest*. The first was the Phi Coefficient. Simply put, the Phi Coefficient is the correlation between how participants labeled beans during the test phase (i.e. good vs. bad) and the actual value of the beans. Thus the Phi Coefficient provides us with a measure of *overall* learning. If participants learned beans well, there should be a large positive correlation between how participants labeled beans and their actual values. Similarly, if participants learned poorly overall, we would expect that actual values and labeled values to be uncorrelated (Phi value ~0). The other variable of interest is the learning asymmetry, which is the proportion of positive beans correct minus the proportion of negative beans correct (positive correct – negative correct). Evaluating the learning asymmetry allows examination of the *relative* level of learning for positive and negative beans. In the case of the learning asymmetry, a value close to zero indicates that individuals learn positives and negatives equally well. A positive value indicates better learning of positive beans than negative beans, while a negative value would indicate better learning of negative beans.

Questionnaire Measures: Several questionnaire measures were utilized to assess depressive symptoms. The Beck Depression Inventory-II (BDI-II; Beck et al., 1996) is a 21-item measure of depressive symptoms experienced within the past two weeks. Each item represents a particular symptom of depression (ex. Sadness, self-criticalness, suicidal thoughts or wishes, and crying). For each item there is a set of statements regarding the particular depressive symptom ranging from low severity to very high severity. Participants must circle the statement which is most similar to what they have experienced within the last two weeks.

The Depression Anxiety Stress Scale (DASS; Lovibond & Lovibond, 1995) is a 42 item measure of symptoms of depression, anxiety, and stress experienced within the past week. Participants rate how applicable each item is to them on a four point scale ranging from 0-3. The DASS is split into three distinct subscales for depression, anxiety, and stress. Sample items from the depression scale include: “I felt sad and depressed”, “I felt I had lost interest in just about everything”, “I couldn’t seem to get any enjoyment out of the things that I did”, and “I just couldn’t seem to get going”. The anxiety scale includes items that tap into autonomic arousal, situational anxiety, and subjective experiences of anxious affect. The stress scale includes items involving difficulty relaxing, nervous arousal, and agitation.

The Adult Temperament Questionnaire Short Form (ATQ Short; Derryberry & Rothbart, 1988) is a 77 item questionnaire with multiple subscales. The subscale of interest to this study was that of activation control. Activation Control is a particular facet of effortful control, and it is defined as the ability to motivate oneself to perform an action when there is not an inherent tendency to complete it. This is the most likely facet of effortful control that could have potentially allowed participants to learn about positive beans, even if they were not particularly motivated to do so.

Results

Descriptive Statistics

The first thing that was done in our analysis was to examine all variable means and distributions. Results are summarized in Table 1 (Appendix B). Because the study involved non-clinically depressed individuals, variables involving depressive symptoms were skewed towards the low end of depressive symptoms. Beanfest variables were approximately normally distributed, although learning was not as good as we would have hoped it would be.

Beanfest Learning

Before examining the relationship between *Beanfest* and depression, it was important to test how well participants learned overall. As stated previously, the phi coefficient represents the correlation between how participants labeled the beans and the actual value of the beans. If participants randomly guessed the value of all beans, we would expect that they would obtain a phi coefficient of zero, representing no relationship. Results confirmed that on average participants learned beans better than would be expected by chance $t(141) = 11.54$, $p = <.001$. However, a significant subgroup of participants obtained phi values that were less than zero. This means that the learning rules these individuals utilized produced the wrong answer more often than guessing randomly. This was a peculiar result, and potential explanations for this are discussed in the conclusions section.

Learning Asymmetry and Depression

Hierarchical regression was used to evaluate the relationship between learning asymmetry and depression cross-sectionally. A separate hierarchical regression, which controlled for baseline depressive symptoms, was used to predict changes in depressive symptoms over time. All measures were standardized (converted to Z-score units) before being entered into the regression analyses. Predictors entered into the first step of the cross-sectional hierarchical regression were gender, learning asymmetry, and the phi coefficient. In the second step the interaction between learning asymmetry and the phi coefficient was added to the model, and the change in R^2 was assessed. For the prospective hierarchical regression, predictors were exactly the same, only baseline depression was controlled for in the first step of this model. Table 2 (Appendix B) shows the cross-sectional and prospective models and its significance when using the DASS Depression Subscale as the dependent variable. BDI-II depressive symptoms were also examined using the same models. Table 3 (Appendix C) shows the cross-sectional and prospective relationship between *Beanfest* variables and changes in BDI-II depressive symptoms. When looking at the entire sample, nothing was revealed to be a significant predictor in the cross-sectional models, nor was anything predictive of changes in depression over the course of the quarter.

Because overall learning on the task was lower than expected and the sample included a substantial minority of participants with negative phi coefficients, additional analyses were conducted on a subsample that excluded those for whom the phi coefficient was negative. It was hypothesized that such participants could obscure the hypothesized effect in those with more typical pattern of responses. One would be expected to perform at or above chance levels in correctly identifying beans as good or bad because there is an inherent 50% chance of being correct when making a dichotomous decision about the valence of each bean (rewarding vs. punishing).

When restricting the sample to those who displayed phi coefficients of greater than or equal to zero, the hypothesized results began to emerge. This restriction dropped 24 participants from the analyses, leaving 99 remaining. Interestingly, neither learning asymmetry nor the learning asymmetry x phi interaction were significant in the cross sectional regression for either the DASS Depression subscale or the BDI-II (see Table 4 in Appendix C). Potential reasons for this finding are discussed in the conclusions section. Even when restricting the sample to participants with Phi coefficients of ≥ 0, the prospective regression was not predictive of changes in BDI-II depressive symptoms over time (see Table 5 in Appendix C). However, the prospective regression revealed that changes in DASS depression throughout the course of the quarter could be predicted by the interaction between learning asymmetry and the Phi coefficient (See Table 6 shown in Appendix D). Adding the interaction term to the model produced an R^2 change of .017 ($p = .037$). An expanded regression table showing regression coefficients and semi-partial correlations for each predictor in both steps of this regression can be found in Table 7 (Appendix D). A plot of predicted points based on the regression model is shown in Figure 3 (Appendix E). By performing simple slope t-tests, it is possible to analyze whether the slope of each line is significantly different from zero. When Phi is high, learning asymmetry is predictive of changes in depression across the quarter ($t = -2.74$, $p = .0074$). That is to say, a negative learning asymmetry predicts increases in DASS depression across the quarter when participants learned well overall. Similarly, a positive learning asymmetry predicts decreases in DASS depression over the course of the quarter when participants learned well overall. When overall learning was poor (low phi) learning asymmetry was not predictive of changes in depression ($t = .909$, $p = .37$). Interestingly, this result was found only when examining DASS Depression Subscale symptoms but not when using BDI-II symptoms as the dependent variable.

Activation Control as a Moderating Factor

It was hypothesized that the Activation Control subscale of the ATQ could potentially modify the relationship between learning asymmetry and changes in depression over time.

When activation control was added to the prospective regression there was not a significant change in R^2, indicating that activation control did not modify the relationship between learning asymmetry and depression cross-sectionally or prospectively. In all regression models the R^2 change never even approached significance (p was always > .30).

Conclusions

Overall, the study yielded mixed results. When including the entire sample, the study failed to replicate a cross-sectional relationship between learning asymmetry and depression, and the learning asymmetry was not found to be a significant risk factor for increases in depressive symptoms. This was primarily due to very poor learning of the beans overall. Having a subgroup of participants who did not even learn at chance levels severely reduced any chance of finding the hypothesized effects. Having participants who failed to perform at chance levels was very perplexing and several explanations are possible. Given that in some cases, the phi coefficient was quite negative (minimum value of -.35), it is possible that some participants intentionally answered incorrectly, and would not be unheard of in a sample composed mostly of college freshman. However, a more likely explanation is that participants simply did not sustain enough motivation to be engaged in the task, and extreme negative values may have been a function of systematically pressing one response key in particular. In reality, both explanations are probably applicable.

Regardless, when removing those individuals who failed to learn at chance levels, we found that a negative learning asymmetry (learning positive beans more poorly than negative beans) was predictive of increases in depressive symptoms across the course of the quarter. Additionally, a positive learning asymmetry predicted a decrease in depressive symptoms across the course of the quarter. Interestingly, this effect was only found in the DASS Depression Subscale, but not the Beck Depression Inventory-II. This most likely represents differences in the types of depressive symptoms that each measure taps into. Because the DASS factors symptoms into depression, anxiety, and stress subscales, many of the dysphoric symptoms that depression shares with anxiety and stress are separated from the anhedonic symptoms which are unique to depression. The BDI-II does not separate symptoms of negative physiological arousal and dysphoria from symptoms involving low sensitivity to rewards and anhedonia. This provides some evidence that the learning asymmetry is especially useful in predicting symptoms of depression that involve a lack of pleasure and reward sensitivity.

Among other things, results of the current study suggest that alterations need to be made to the *Beanfest* learning paradigm in order to elicit better learning from participants. Given the inexplicably low Phi values, it seems that motivating participants to be fully engaged in the task was a problem in the current study, and steps need to be taken to ensure that the program is changed in such a way as to elicit a level of learning among participants that is vastly improved over the level displayed by the current sample.

One of the things that was apparent when running participants through the research protocol is that the script used to instruct participants on how to complete *Beanfest* was unsatisfactory. Instructions were long and repetitive, while at the same time, not very engaging. Participants often seemed disengaged before the task even started.   Another problem could lie in the program itself not being very engaging. The program is a fairly mundane exercise, with the only visual reinforcement for correctly accepting rewarding beans being a +10 displayed at the bottom of the computer screen. Likewise the only punishing aspect of wrongly selecting negative beans is a -10 flashed on the screen. Perhaps visually stimulating feedback designed to celebrate the fact that participants selected rewarding beans and ridicule them for selecting punishing beans would provide an intrinsic reward/punishment motivation.

In the case that intrinsic reward is not enough to motivate participants to learn the beans better, extrinsic motivation in the form of more substantial subject payment is another potential aspect of the design that could be improved (assuming the necessary funding prerequisites are met). On average, participants did not earn a very substantial amount of money by completing *Beanfest*, and even if they performed well, the maximum amount of money that could be earned was a fairly paltry amount. One problem in the current study was that participants were not paid until the end of the quarter. This was because the current study was part of a larger study in which participants were being paid for completion of other tasks as well as *Beanfest*. It was more convenient to pay one lump sum at the end of the quarter than to have money on hand for every session. Immediate payment might be a better motivator than payment delayed for eight weeks. In hindsight, it appears that this is another aspect of the study design that needs to change in future iterations of *Beanfest.*

The current study was limited by several factors. Primarily, the study examined learning in a sample of college undergraduates, the majority of whom displayed very few depressive symptoms. This skewed the distribution of depressive symptoms towards the low end of all dependent variables, which presented problems when trying to analyze differences in depressive symptoms because variability in depressive symptoms was somewhat restricted. Depending on the aims of future studies, it may be beneficial to utilize an extreme groups design in which clinically depressed vs. non-depressed individuals are compared in their learning asymmetry over time.

The time frame which the current study operated within was also potentially a limiting factor on the effect sizes that could be observed. Utilizing the academic quarter as a timeframe for the prospective relationship between learning asymmetry and depressive symptoms was convenient, but participants' depressive symptoms can only change to a limited extent over the course of 10 weeks. Again, if funding were sufficient, a longer timeframe would be more ideal to examine changes in depressive symptoms over time.

Even given the limitations of time, money, and a demonstrated lack of motivation in some subjects, the current study found effects compatible with original hypotheses. Given sufficient overall performance in learning the game beans, learning asymmetry is a significant predictor of anhedonic symptoms of depression over time, as evidenced by its relationship with the DASS Depression Subscale. It appears that this relationship is primarily and specifically true with anhedonic symptoms of depression because learning asymmetry was not predictive in changes in BDI-II depressive symptoms, which is slanted towards symptoms of negative physiological arousal and dysphoria. Effortful control does not seem to be a modifying factor in learning asymmetry's relationship to changes in depression as evidenced by the complete lack of predictive capability.

This finding provides evidence for the importance of cognitive processing of positive information in depression. This has implications for future cognitive models of depression in that, a complete picture of cognitive processes involved in depression includes not only how negative objects/experiences are processed, but also how positive objects/experiences are processed. It has been shown that depressed individuals are biased in their processing of negative cues, but current findings suggest that biased processing of positive cues, or a low level of reward sensitivity, is also important to depression.

The logical next step in the present line of research is to test for a causal relationship between learning asymmetry and depression. That is, if it is possible to alter the learning asymmetry observed in *Beanfest*, does that also produce changes in depressive symptoms? If this proves to be true, the learning asymmetry found in *Beanfest* becomes a very important explanatory variable in the cause and maintenance of depressive symptoms. Additionally, *Beanfest* could become an important tool in early identification of those at risk for development of depression. It is even possible that cognitive retraining on the *Beanfest* task could have therapeutic value in reducing depressive symptoms. The future in this line of research appears to be bright and filled with possibilities.

Appendix A

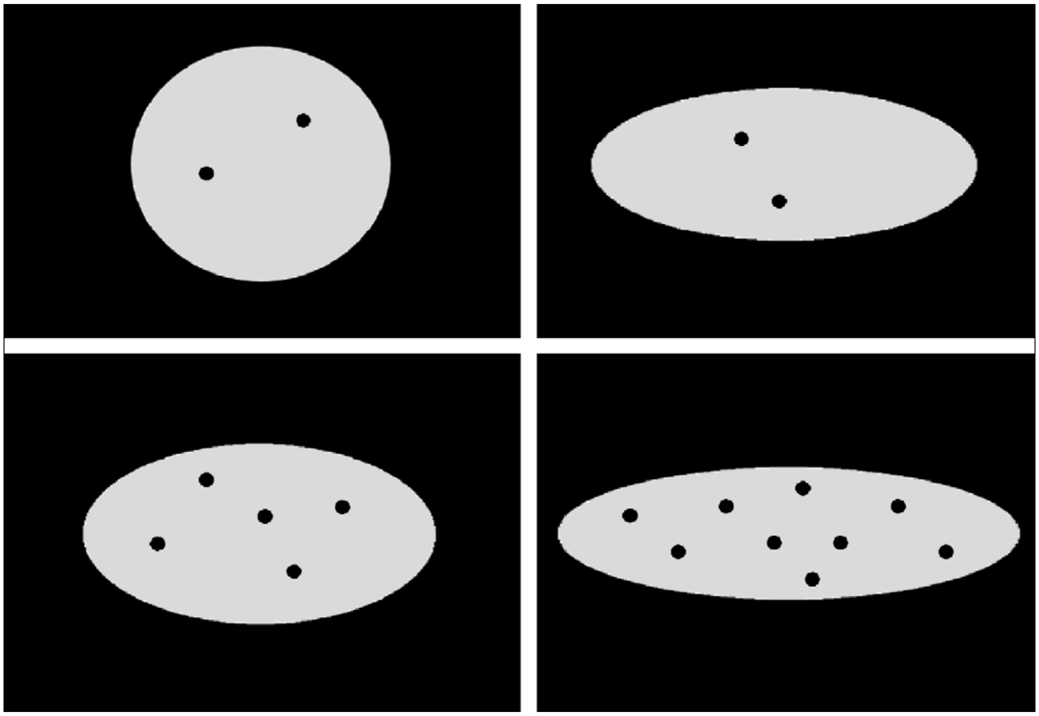

Figure 1: Various images of beans as they appear in the game. As can be seen they vary in both shape and number of speckles

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
X1	10	10	10			-10	-10	-10		
X2	10	10			-10	-10	-10			
X3						-10				
X4									10	
X5		-10						10	10	10
X6	-10	-10	-10						10	10
X7	-10	-10								
X8					10					
X9				10	10	10			-10	-10
X10			10	10	10			-10	-10	-10

Figure 2: Matrix of the beans. The X dimension represents shape of the bean from 1 (circular) to 10 oblong. The Y dimension is the number of speckles (1-10). Regions with point values represent beans used during the learning phase.

Appendix B

Table 1: Descriptive Statistics

Variable	Mean	SD	Min	Max
Phi Coefficient	.24	.25	-.35	.95
Learning Asymmetry	-.03	.19	-.61	.39
BDI-II Beginning	9.57	8.88	0	42
DASS Depression Beginning	5.66	7.53	0	41
DASS Anxiety Beginning	5.62	6.03	0	36
DASS Stress Beginning	11.20	9.17	0	40
ATQ Activation Control	34.36	7.21	11	49
BDI-II End	9.21	9.26	0	39
DASS Depression End	5.66	6.91	0	38
DASS Anxiety End	5.26	6.24	0	33
DASS Stress End	10.41	9.23	0	38
Proportion of Beans Correct	.62	.12	.33	.97

Means, Standard Deviations, Minimum Values, and Maximum Values of all variables

Table 2: Regression Models for DASS Depression in the Entire Sample

Dependent Variable: Time 1 DASS

Cross-Sectional Regression	R^2 Change
Step 1: Sex, Phi, Learning Asymmetry	.013
Step 2: Learning Asymmetry x Phi Interaction	.003

Dependent Variable: End Quarter DASS

Prospective Regression	R^2 Change
Step 1: Sex, Depression Time 1, Phi, Learning Asymmetry	.64**
Step 2: Learning Asymmetry x Phi Interaction	.008

Regression models including the entire range of participants; *Denotes significance at the .05 Level, ** Denotes significance at the .01 Level

Note: In the prospective regression, the model is significant, but only because the control variable of Depression Time 1 is strongly related to end of the quarter depression. None of the variables of interest were significant

Appendix C

Table 3: Regression Models for BDI-II Depression in the Entire Sample

Dependent Variable: Time 1 BDI-II

Cross-Sectional Regression	R^2 Change
Step 1: Sex, Phi, Learning Asymmetry	.056
Step 2: Learning Asymmetry x Phi Interaction	.000

Dependent Variable: End Quarter BDI-II

Prospective Regression	R^2 Change
Step 1: Sex, Depression Time 1, Phi, Learning Asymmetry	.692**
Step 2: Learning Asymmetry x Phi Interaction	.000

Regression models including the entire range of participants; *Denotes Significance at the .05 Level, ** Denotes significance at the .01 Level

Note: In the prospective regression, the model is significant, but only because the control variable of Depression Time 1 is strongly related to end of the quarter depression. None of the variables of interest were significant

Table 4: Cross-Sectional Regression Models for DASS Depression and BDI-II in the Reduced Sample (n=99) who Displayed Phi ≥ 0

Dependent Variable: Time 1 DASS

Cross-Sectional Regression	R^2 Change
Step 1: Sex, Phi, Learning Asymmetry	.009
Step 2: Learning Asymmetry x Phi Interaction	.006

Dependent Variable: Time 1 BDI-II

Cross-Sectional Regression	R^2 Change
Step 1: Sex, Phi, Learning Asymmetry	.042
Step 2: Learning Asymmetry x Phi Interaction	.001

Cross-Sectional regression models including only those participants who had a Phi value ≥ 0;
*Denotes significance at the .05 Level, ** Denotes significance at the .01 Level

Table 5: Prospective Regression Model for BDI-II Depression in the Reduced Sample (n=99) who Displayed Phi ≥ 0

Dependent Variable: End Quarter BDI-II

Prospective Regression	R^2 Change
Step 1: Sex, Depression Time 1, Phi, Learning Asymmetry	.693**
Step 2: Learning Asymmetry x Phi Interaction	.001

Regression model predicting change in BDI-II depression scores
Only participants with a Phi value ≥ 0 were included in this regression model
*Denotes significance at the .05 Level, ** Denotes significance at the .01 Level

Appendix D

Table 6: Regression Table Predicting Change in DASS Depression Subscale in the Reduced Sample (n=99) who Displayed Phi ≥ 0

Dependent Variable: End Quarter DASS Depression

Prospective Regression	R^2 Change
Step 1: Sex, Depression Time 1, Phi, Learning Asymmetry	.631**
Step 2: Learning Asymmetry x Phi Interaction	.017*

Regression model predicting change in DASS depression scores
Only participants with a Phi value ≥ 0 were included in this regression model
*Denotes significance at the .05 Level, ** Denotes significance at the .01 Level

Table 7: Expanded View of the Regression Coefficients and Semi-Partial Correlations when Predicting Change in DASS Depression Subscale in the Reduced Sample (n=99) who Displayed Phi ≥ 0

Step 1:

Predictor	b	sr	R^2
Full Model	-	-	.631**
(Constant)	-.028	-	
Sex	.091	.082	
T1 DASS Depression	.819**	.775	
Phi Coefficient	-.024	-.019	
Learning Asymmetry	-.110	-.098	

Step 2: Added Asymmetry x Phi interaction to the model

Predictor	b	sr	R^2
Full Model	-	-	.648**
(Constant)	-.036	-	
Sex	.090	.082	
T1 DASS Depression	.836**	.785	
Phi Coefficient	-.047	-.038	
Learning Asymmetry	-.076	-.066	
Asymmetry x Phi	-.198*	-.130	

Note: b=slope, sr = semi-partial correlation; *Denotes significance at the .05 level
Regression model includes only those individuals who had Phi values ≥ 0
Asymmetry x Phi Interaction is significant at the .05 level

Appendix E

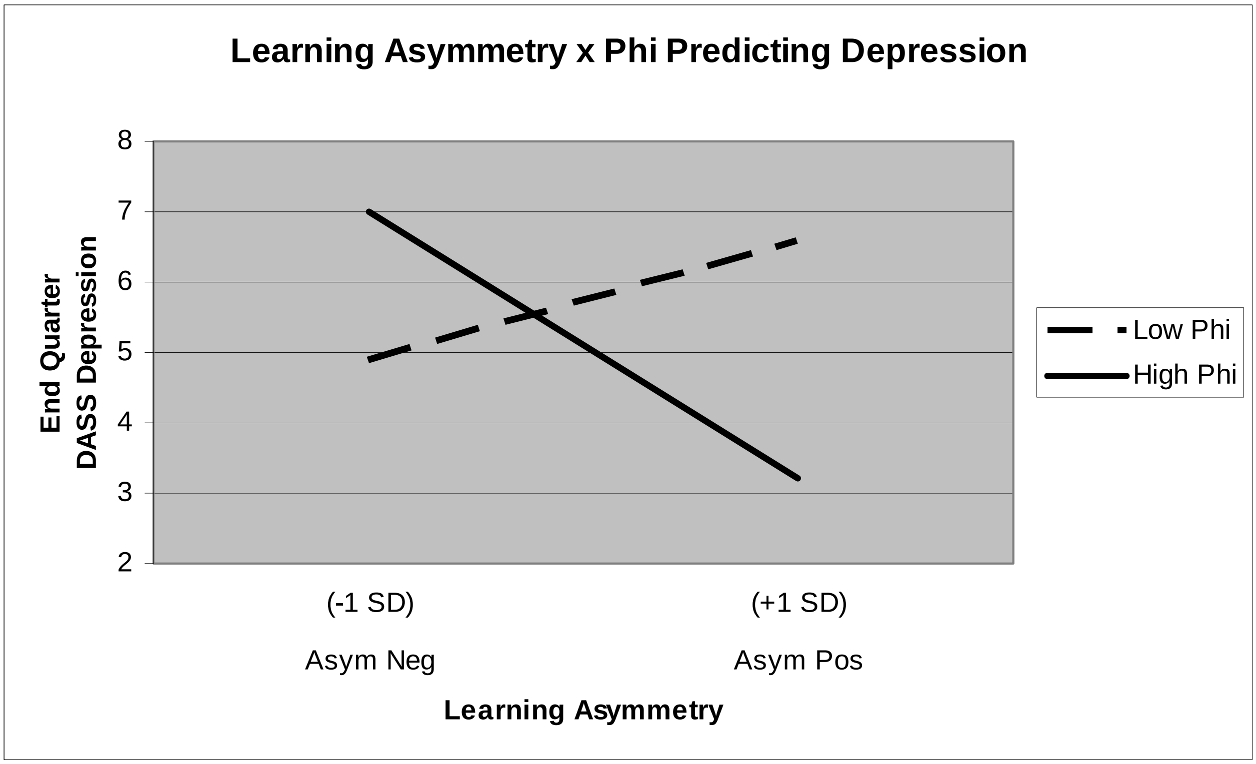

Figure 3: Learning asymmetry predicting change in depression at low and high levels of phi
Note: All variables are in standard deviation units

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